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SEDIMENTATION INVESTIGATION

OF

CARNEGIE LAKE, PRINCETON, N. J.

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Introduction

Carnegie Lake is a shallow channel-type lake created in 1907 on the Millstone River, 2 miles northeast of Princeton, N. J. It is impounded by a concrete overflow dam, 650 feet long and 18 feet high above streambed. Backwater extends up Stony Brook, a principal tributary, thus forming a Y-shaped lake approximately 3-1/2 miles long. There is no overbank storage.

The lake was constructed for recreational purposes and is used by Princeton University for rowing and other aquatic sports. The University boathouse is located on the left bank of the Stony Brook arm of the lake about 1/2 mile below the head of backwater. A canoe house has been constructed about a mile below the boathouse.

Two bridges span the Stony Brook arm of the lake, the Washington Street bridge 500 feet below the University boathouse, and the Harrison Street bridge approximately 3,800 feet below the boathouse. The Delaware and Raritan Canal, which runs along the right bank of the lower section of the lake, crosses Carnegie Lake by means of a low aqueduct just above the Stony Brook arm. This aqueduct, together with the shallow and weedy nature of the section of the lake on the main stem above the aqueduct, causes most of the aquatic activity to be concentrated in the Stony Brook arm of the lake rather than the main stem above the junction of the two arms.

Sedimentation Investigations

An investigation of sedimentation conditions in Carnegie Lake made by the writer on July 18, 1939, showed that the lake has passed through a varied and unique sedimentation history. Silting in the Stony Brook arm of the lake was noticed immediately after the lake was impounded. It was not until 1922, however, that officials became concerned about the situation when motorboats, used by coaches for training rowing crews, scraped bottom on their way to and from the boathouse. A survey to determine the water depth between the head of backwater and the Harrison Street bridge, an area of 52.32 acres, was made by the University during July 1922. A map on the scale of 1 inch equals 100 feet was prepared of the area, and over 500 soundings were made along 43 separate ranges. On the basis of these soundings the writer has calculated that approximately 62 acre-feet of sediment had been deposited in this area up to 1922.

This would be equal to at least 25 percent of the original capacity of this portion of the lake.

After the 1922 survey was made, it was decided that by raising the water level of the reservoir several inches enough clearance could be developed to permit the boats to move readily for some time at least. Consequently, a 4-inch board was placed on the spillway and the water surface of the reservoir raised a corresponding amount. This temporary expedient served until 1927 when Mr. A. E. MacMillan, Superintendent of Buildings and Grounds at Princeton University, constructed an improvised dredge and attempted to open a channel from the boathouse to deeper water. It is his estimate that between 4,000 and 5,000 cubic yards (approximately 3 acre-feet) of sediment was removed from the lake at this time.

By 1937, conditions had become considerably worse. The University found it necessary to purchase a dredge and clean out the entire area from Harrison Street bridge to the head of backwater. This operation was started early in 1937 and continued intermittently until 1938. A crew of 6 men was employed to do the work on an 8-hour shift. By July 1937, 50,000 cubic yards (31 acre-feet) of sediment had been pumped from the lake and deposited in a depression between the right bank of the lake and the Delaware and Raritan Canal. In 1938, between 100,000 and 110,000 cubic yards (65 acre-feet) of sediment was removed. A small amount of dredging was done in 1939, but figures relative to the amount of material removed are not obtainable. Thus, approximately 100 acre-feet of sediment was removed from bank to bank in the area between Harrison Street bridge and the head of backwater between 1937 and 1939. The net operating cost of this work is reported to have been over $17,000 or about 11 cents per cubic yard removed.

The 100 acre-feet of material dredged from the lake supposedly included 6 to 8 inches of the original bottom to provide for additional sediment storage. At the head of the lake, just below the Pennsylvania Railroad bridge, a sediment pocket was excavated to a depth of 8 feet where formerly the original depth was only about 2 feet. This sediment pocket was to provide additional sediment storage to prevent the initial deposits after dredging from encroaching upon the vicinity of the boathouse located 1/2 mile below. At the time the lake was dredged it was presumed that the sediment pocket and the extra capacity created by the removal of 6 or 8 inches from the bottom of the lake would provide sufficient sediment storage space to eliminate the silting problem for 30 years.

A sedimentation investigation was made by the writer on July 18, 1939, primarily to determine the extent of silting since 1938 in the dredged area of Stony Brook arm and to determine the source of this erosional debris. A series of 8 ranges was laid out across the lake

and 36 observations of sediment thickness were made with a spud along these ranges. The data were plotted on cross-section paper, and the volumes of sediment and volumes of water in different channel segments after dredging were determined by the following mean depth formula:

$$V = \frac{A}{3}\left(\frac{E1}{W1} + \frac{E1 + E2}{W1 + W2} + \frac{E2}{W2}\right)$$

Where V is the volume in acre-feet, A the surface area between ranges in square feet, E the cross-sectional area in square feet, and W the length of the bounding range in feet at crest elevation.

Since the original bottom of the lake was obliterated to some extent by dredging, the original volume of the area above Harrison Street bridge could not be determined directly. On the basis of this investigation, however, it was determined that the volume of this part of the lake after dredging was 252 acre-feet. If this amount included an average of 6 inches of original bottom over the entire area, then the original volume must have been about 220 acre-feet and the 62 acre-feet of sediment deposited up to 1922 was equal to about 28 percent of the original capacity.

The amount of recently deposited sediment in the dredged area was found to be 61 acre-feet in July 1939. In other words, 61 acre-feet or a quarter of the capacity established by dredging from 1937 to early 1939 was lost by July 1939. The silt pocket established at the head of the lake had been reduced from a depth of 8 feet to a depth of 2 feet by a deposit of sand and gravel reported to have been brought down by a single freshet. The situation, however, is not as severe as it might appear from these data. Although 61 acre-feet of sediment was actually measured in 1939, equal in volume to all the sediment carried in during the 15-year period 1907 to 1922, this sediment was very flocculent and poorly compacted. Observations of undisturbed sediment deposits in other sections of the lake revealed an unusually well compacted argillaceous sediment which greatly resisted the penetration of the spud. The sediment, which adhered to the spud when it was brought up from the bottom, was noticeably plastic and so compacted that it could be removed from the spud in some cases by peeling. This would indicate that the sediment carried into the dredged portion is capable of undergoing considerable additional compaction and resultant reduction in volume. Although no actual tests were carried out, it is believed that this reduction in volume might amount to as much as 50 percent.

A number of spud observations were made below Harrison Street bridge, but no reliable estimate can be made of the total amount of sediment deposited in this area because complete penetration of the highly compacted sediment could not be accomplished with the spud.

Penetration was usually limited to less than 2-1/2 feet, even though the spud was thrown with great force. The average depth of sediment at the dam was determined to be 5.6 feet, with a maximum depth of 7.0 feet. A longitudinal section was plotted on cross-section paper showing the average water depth for each range below Harrison Street bridge and the probable average bottom elevation determined from available data. This indicated that approximately 40 percent of the original storage capacity of the undredged portion below Harrison Street had been lost because of silting during the 30 years following closing of the dam.

Sources of Sediment

The drainage area of Carnegie Lake presents a clear picture of the relationship of reservoir silting to different watershed conditions. The total watershed area of the lake is 160 square miles, which includes Stony Brook with a drainage area of 50 square miles. Although the Stony Brook watershed area is less than half as large as that of the Millstone River, it contributes practically all of the sediment to Carnegie Lake.

Carnegie Lake lies on the boundary between two physiographic provinces, the Piedmont Plateau and the Atlantic Coastal Plain. The Millstone River rises in and flows through the coastal plain area, which is characterized in this region by level to gently rolling topography. The Millstone is a sluggish river of low gradient with generally wide stream bottoms. Its headwaters are located in an area dominated mainly by sandy loam or fine sandy loam soils of the Collington series derived from unconsolidated sands, silts and clays. The largest part of the drainage area above Carnegie Lake, however, is composed of the sandy soils of the Sassafras series which are similar in texture to the Collington soils in this area.

Because of the low slopes and absorptive nature of the soil in the Millstone watershed, very little sediment finds its way into the Millstone River. The two largest tributaries of the Millstone River above Carnegie Lake, Bean Brook and Cranbury Brook, have dams constructed on them within a half mile above their confluence with the Millstone and in each case less than two miles above the head of backwater of the lake. A dam on the main stem at Hightstown is about 7 miles above the head of backwater. No less than 8 dams have been constructed on the Millstone River and principal tributaries above Carnegie Lake. These catch most of the sediment that is derived from this drainage area. Above the Delaware and Raritan aqueduct, which marks the junction of the Millstone River and the Stony Brook arm of the lake, there is a rank growth of vegetation, and fishing seems to be at its best here.

In contrast, the Stony Brook tributary rises in and flows through the Piedmont Plateau which is characterized by a rolling to hilly topography. Stony Brook itself is a winding stream of high gradient which in places has cut a narrow, steep-sided channel. The soils of the Stony Brook watershed are composed mainly of silt loams of the Lansdale, Penn and Montalto series, derived from soft red and gray sandstones, shales and fine-grained argillites of Triassic age. They are easily eroded. No dams have been constructed on Stony Brook or any of its tributaries, and, therefore, practically all of the sediment washing into the stream in the watershed finds its way eventually into Carnegie Lake. As a result, heavy silting has taken place in the Stony Brook arm of the lake and in the main part of the lake below the junction of Stony Brook and the Millstone River.

Although time did not permit a detailed study of sediment sources in the drainage area, it is obvious that any further provisions for protecting the reservoir, other than dredging or raising the dam, both of which have their limits, must include protective works in the Stony Brook watershed.